PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 9: THERMODYNAMICS

THERMAL ENERGY TRANSFER AND TEMPERATURE

SCORE	PERCENTAGE
/150	%

STEMUP

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Q1.

Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

melting point of aluminium = 660 K
specific heat capacity of aluminium = 902 J kg^{-1} K^{-1}
specific latent heat of aluminium = 396 kJ kg^{-1}
room temperature = 293 K
mobile phone p.d. = 3.7 V
mobile phone current = 120 mA

(6)

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(Total for question = 6 marks)

Q2.

Latte is a type of coffee made with hot frothy milk. The milk is heated by pumping steam into it.

Calculate the maximum mass of milk that could be warmed to a temperature of 65 °C by absorbing 15 g of steam at 100 °C.

initial temperature of milk = 4.0 °C
specific heat capacity of milk = 3900 J kg^{-1} K^{-1}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific latent heat of vaporisation of water = 2.3 × 10^{6} J kg^{-1}

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Maximum mass = ...

(Total for question = 4 marks)

Q3.

A data book contains the following information for ethanol.

latent heat of fusion = 109 kJ kg^{-1}

latent heat of vaporisation = 838 kJ kg^{-1}

545 J is transferred from a sample of ethanol when it condenses.

Which of the following shows how to calculate the mass of ethanol that condenses?

(1)

☒ **A** 545 ÷ 109 000

☒ **B** 545 ÷ 838 000

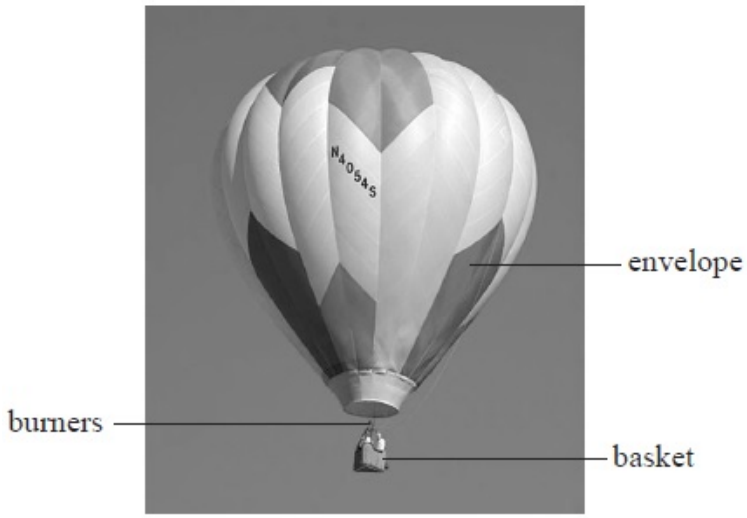
☒ **C** 109 000 ÷ 545

☒ **D** 838 000 ÷ 545

(Total for question = 1 mark)

Q4.

Hot air ballooning is one way to explore the landscape. Air in a balloon is heated from underneath by a set of burners and the balloon starts to rise.



(a) Explain why heating the air causes the balloon to rise.

(2)

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(b) In 1991, Per Lindstrand and Richard Branson become the first people to cross the Pacific in a hot air balloon.

With a volume of 7.4×10^4 m^3 the balloon was, at the time, the largest ever built.

Calculate the energy supplied by the burners to heat the air from 20.0 °C to 35.0 °C.

average density of air in the balloon = 1.20 kg m^{-3}

specific heat capacity of air = 1010 J kg^{-1} K^{-1}

(3)

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Energy = ...

(c) The first balloons used were filled with hydrogen and sealed to keep the volume constant. As the balloon rose there would be changes in the pressure of the hydrogen due to the temperature changes of the atmosphere.

(i) Calculate the new pressure exerted by the hydrogen if the temperature changed from 20.0 °C to −5.0 °C, as the balloon rose from ground level.

pressure exerted by the hydrogen in the balloon at ground level = 1.01×10^5 Pa

(2)

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New pressure = ...

(ii) State **two** assumptions that you must make to calculate this change.

(2)

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*(iii) By considering the motion of molecules in the gas, explain why the pressure exerted by the gas decreases as it cools.

(3)

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(Total for Question = 12 marks)

Q5. The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

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Resistance = ...

(b) Water enters the shower at a temperature of 7.5 °C.

Calculate the water flow rate required to give an output temperature of 37.5 °C.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(3)

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Flow rate = ...

(Total for Question = 5 marks)

Q6.

It was suggested on an online forum that it would be possible to cook a chicken by repeatedly slapping the chicken with one hand.

It was claimed that the energy transferred to a chicken in 8000 slaps would be sufficient to raise the temperature of the chicken from 23 °C to 165 °C.

In an investigation to test the claim, the effective mass of the hand was taken as 1.75 kg and the speed of the hand just before impact with the chicken as 6.25 m s^{-1}.

Deduce whether the data confirms that 8000 slaps would be sufficient.

Assume that no energy is transferred from the chicken to the surroundings.

mass of chicken = 0.875 kg

specific heat capacity of chicken = 1770 J kg^{-1} K^{-1}

efficiency of energy transfer from the hand = 65%

(5)

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(Total for question = 5 marks)

Q7.

An electric iron rated at 2600 W contains a steel plate which is heated to a working temperature of 215°C. Room temperature is 18°C.

Deduce whether the plate could reach its working temperature in less than 1 minute.

mass of steel plate = 890 g

specific heat capacity of steel = 450 J kg^{-1} K^{-1}

(3)

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(Total for question = 3 marks)

Q8.

A cup contains 180 g of black coffee at a temperature of 82 °C. 68 g of milk at a temperature of 2.7 °C is added to the coffee. An ideal temperature range for drinking coffee is said to be 50 °C to 60 °C.

Deduce whether the coffee will be within the ideal temperature range when the milk is added.

initial temperature of milk = 2.7 °C

specific heat capacity of black coffee = 4.2×10^3 J kg^{-1} K^{-1}

specific heat capacity of milk = 3.9×10^3 J kg^{-1} K^{-1}

(3)

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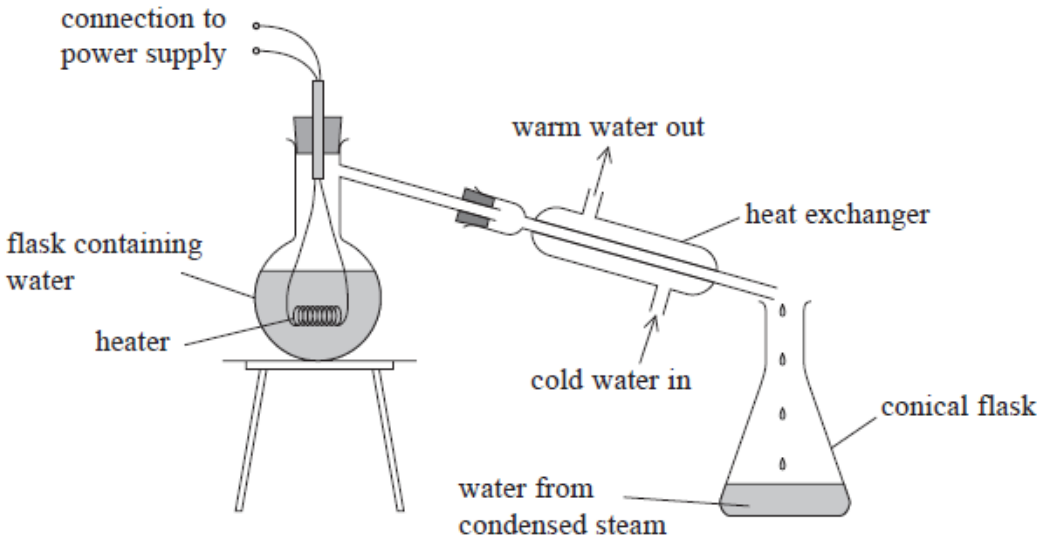
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(Total for question = 3 marks)

Q9.

The apparatus shown can be used to determine a value for the specific latent heat of vaporisation of water.



(a) In one experiment the current in the heater was 8.20 A, and the potential difference across the heater was 230 V.

(i) Show that the power of the heater was about 2 kW.

(2)

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(ii) There was 0.655 kg of water in the flask at an initial temperature of 22.5 °C.
The heater was switched on, and the water in the flask was heated to boiling point.

Calculate the minimum time taken for the water to be heated to 100.0 °C.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

(3)

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Minimum time taken for water to be heated = ...

(b) The heater was left on and water continued to boil in the flask. The water was allowed to boil for a few minutes. The conical flask was then placed under the heat exchanger and water was collected in it.

(i) Give a reason why the water was left boiling for a few minutes before the conical flask was put in place.

(1)

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(ii) Water with a mass of 95.0 g was collected in a time of 125 s.

Calculate the rate of energy transfer in the heat exchanger.

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(3)

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Rate of energy transfer in the heat exchanger = ...

(iii) Discuss your answers to (a)(i) and (b)(ii).

(3)

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(Total for question = 12 marks)

Q10.

(a) Explain what is meant by internal energy of a liquid.

(2)

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(b) A cup of tea contains 175 g of water at a temperature of 85.0 °C. Milk at a temperature of 4.5 °C is added to the tea and the temperature of the mixture becomes 74.0 °C.

(i) Show that the internal energy of the water decreases by about 8 kJ as its temperature decreases.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(2)

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(ii) Calculate the mass of milk that was added to the tea. State an assumption that must be made.

Specific heat capacity of milk = 3900 J kg^{-1} K^{-1}

(3)

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Mass of milk = ...

Assumption

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(Total for question = 7 marks)

Q11.

Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

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Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

$$^{14}_{7}\mathrm{N} + ^{4}_{2}\alpha \rightarrow \ ____\mathrm{O} + \ ____^{1}\mathrm{p}$$

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

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(b) Uranium-235 is able to undergo fission when it absorbs a neutron to become uranium-236. The equation below shows a possible fission reaction

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3 \times ^{1}_{0}n$$

Use the data in the table to show that the energy released by the fission of one uranium nucleus is about 170 MeV.

Isotope	Mass / 10^{-27} kg
^{235}U	390.29989
^{141}Ba	233.99404
^{92}Kr	152.64708
^{1}n	1.67493

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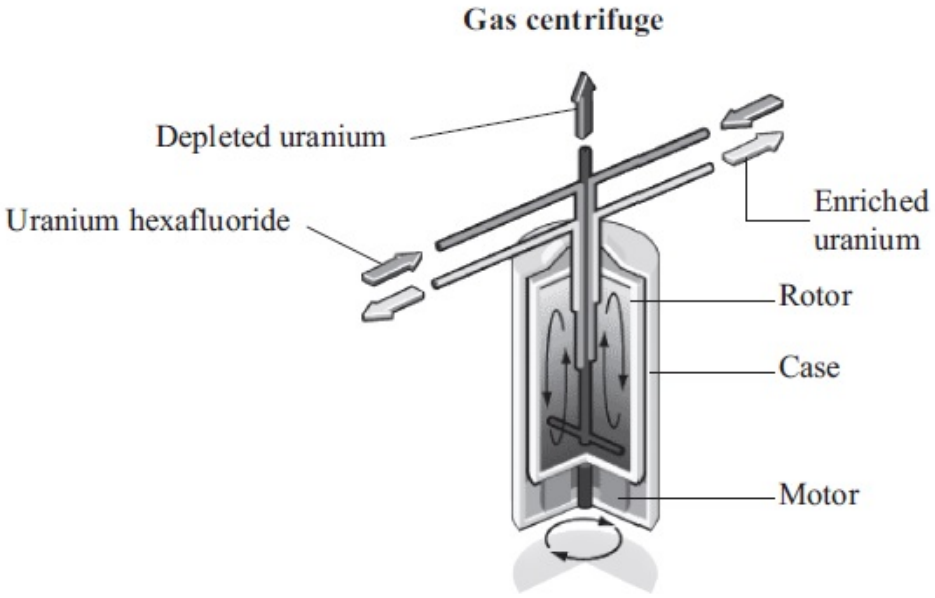
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(c) Naturally occurring uranium is more than 99% uranium-238. Fuel for a fission reactor requires at least 3% of the uranium to be uranium-235.

Uranium hexafluoride gas is used during the uranium enrichment process. It is fed into a centrifuge, and a rotating cylinder (rotor) sends the uranium-238 to the outside of the cylinder, where it can be drawn off, while the uranium-235 diffuses to the center of the cylinder.



(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

(2)

Similarity

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Difference

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(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute

Calculate the centripetal acceleration at the rim of the motor.

(2)

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Centripetal acceleration = ...

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1

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Property 2

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(d) The waste heat from some power stations is transfered to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of 7.0×10^4 kg s^{-1}. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.



Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water = 3990 J kg^{-1} K^{-1}

(4)

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Efficiency = ...

(Total for question = 16 marks)

Q12.

The photograph shows a 'quiet boil' electric kettle. The makers of the kettle claim that it boils water with much less noise than a standard kettle.



A laboratory technician takes some measurements to compare a 'quiet boil' electric kettle with a standard electric kettle.

The table shows the results recorded by the technician.

	Quiet boil kettle	Standard kettle
Mass of water / kg	1.20	1.20
Initial temperature of water / °C	10	10
Final temperature of water / °C	100	100
Potential difference / V	243	247
Current / A	11.9	11.8
Time taken to heat water to boiling point / s	168	172
Average sound intensity / mW m^{-2}	3.72	10.5

A student uses the values in the table to calculate the efficiency of each kettle at heating the water to boiling point. He calculates the efficiency of the 'quiet boil' kettle to be 0.93

Calculate the efficiency of the standard kettle.

specific heat capacity of water = 4180 J kg^{-1} K^{-1}

(4)

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Efficiency = ...

(b) The intensity of the sound produced by each kettle was measured with a sound meter which was 30.0 cm from the centre of the kettle.

Calculate the energy transferred by sound while the water in the standard kettle is brought to the boil. You may treat the kettle as a point source.

(4)

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Energy transferred = ...

(c) The label on the original packaging of the quiet boil electric kettle states, 'This kettle is much more efficient than a standard kettle because it produces less sound.'

Explain the extent to which this statement is supported by your calculations.

(2)

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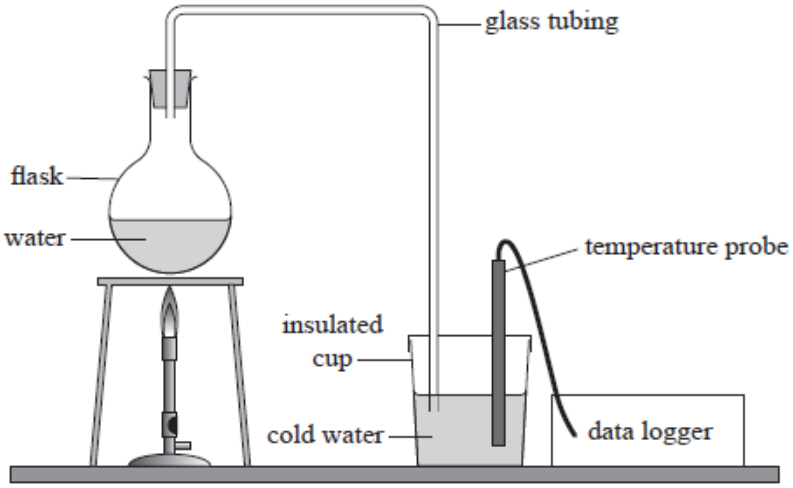
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(Total for question = 10 marks)

Q13.

A student carried out an experiment to determine the specific latent heat of vaporisation of water using the apparatus shown.



The water in the flask was heated and steam was forced out of the flask and through the glass tubing into the cold water in the insulated cup. The steam condensed as it passed into the cold water.

(i) Explain why the water was heated to boiling point and left boiling for a few minutes before the insulated cup of cold water was put in place.

(2)

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(ii) Identify a significant source of error in this experiment and the steps that should be taken to minimise its effect on the calculated value of the specific latent heat of vaporisation of water.

(2)

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(Total for question = 4 marks)

Q14.

It is suggested that before making tea in a teapot, the teapot should be warmed by pouring hot water into it. This allows more flavour to be extracted from the tea.

(a) Suggest why a pre-warmed teapot may allow more flavour to be extracted.

(1)

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(b) (i) 0.26 kg of water at 95 °C is added to a stainless steel teapot. In a very short time the teapot and water both reach a temperature of 81 °C.

Show that the energy transferred from the water is about 15 kJ.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(2)

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(ii) Calculate the specific heat capacity of stainless steel, stating any assumption you make.

mass of teapot = 0.43 kg
initial temperature of teapot = 22 °C

(3)

Assumption

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Specific heat capacity = ... J kg^{-1} K^{-1}

(iii) The accepted value for the specific heat capacity of stainless steel is about 500 J kg^{-1} K^{-1}. Compare this with the value you have calculated and explain the difference.

(2)

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(Total for question = 8 marks)

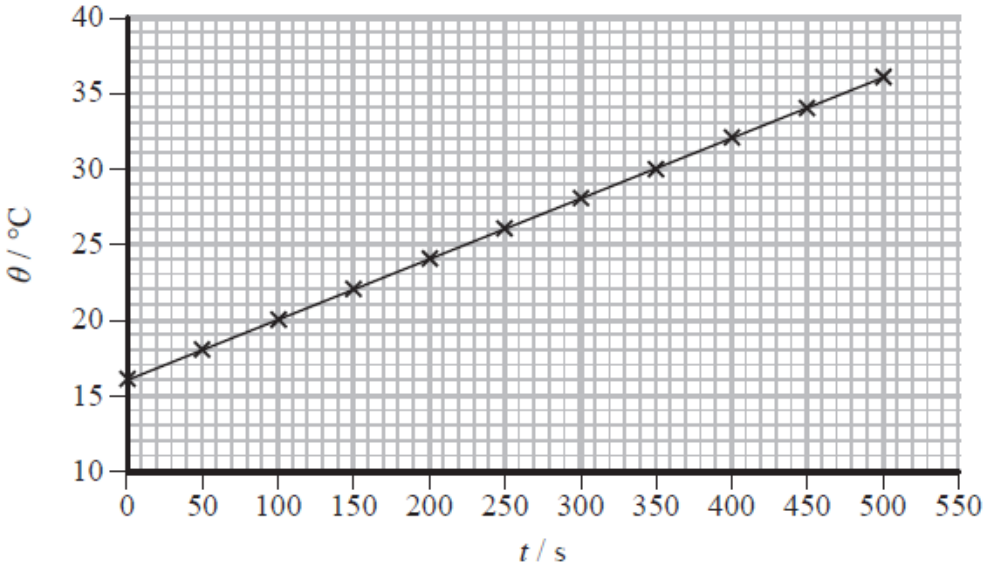
Q15.

A student determined the specific heat capacity of aluminium.

She used an electrical heater to heat an aluminium block and measured the temperature of the block with a digital thermometer.

The student monitored the temperature θ of the aluminium block over the time t for which the heater was switched on.

Her results are plotted on the graph.



(i) Determine the specific heat capacity of aluminium.

power of heater = 37.5 W

mass of aluminium block = 0.986 kg

(3)

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Specific heat capacity of aluminium = ...

(ii) The student looked up the accepted value for the specific heat capacity of aluminium. Using this value, the student predicted that it should have taken 240 s for the temperature of the aluminium block to increase by 10 °C.

Explain the difference between the predicted time and the student's actual observations.

(2)

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(Total for question = 5 marks)

Q1.

When a large potential difference is applied to a discharge tube, the gas in the discharge tube emits coloured light. When this light is passed through a diffraction grating, an emission spectrum which is made up of a series of lines of different wavelengths may be seen.

The photographs show the spectra produced from a tube containing hydrogen and a tube containing helium.

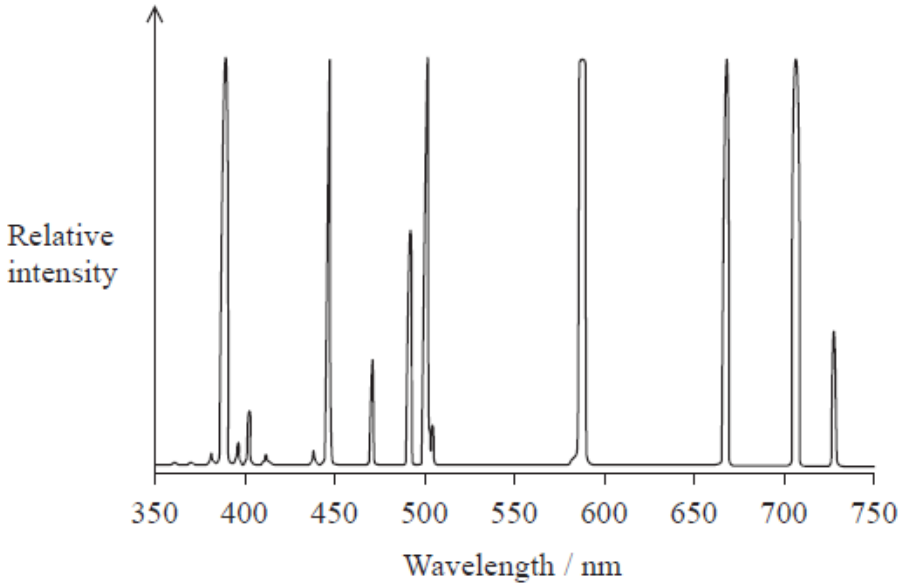
Hydrogen:



Helium:



The graph shows the relative intensities of different wavelengths of light in the spectrum of a sample of helium.



The graph shows that the lines are not at a single wavelength. This effect is known as thermal Doppler broadening and occurs because of the random motion of the helium atoms.

(i) Explain why the thermal motion of the helium atoms causes the broadening of the spectral lines.

(2)

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(ii) The width of a line may be used to determine the speed of the atoms in the gas and hence the temperature of the gas.

The spectral line with wavelength 587 nm for a particular tube containing helium has a width of 6×10^{-3} nm.

(1) Show that this corresponds to a speed, for a helium atom, of about 1500 m s^{-1}.

(2)

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(2) Assuming that this is the root mean square speed for the helium (He 4) atoms in the tube, calculate the temperature of the gas in the tube.

(3)

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Temperature = ...

Q2. When energy is supplied to a substance, changes in the average molecular kinetic energy (E_k) and the average molecular potential energy (E_p) can occur.

When energy is supplied to an ideal gas

☒ **A** both E_k and E_p increase.

☒ **B** E_k may increase.

☒ **C** E_p may increase.

☒ **D** E_k increases but E_p decreases.

(Total for Question = 1 mark)

Q3.

(a) Explain what is meant by internal energy of a liquid.

(2)

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(b) A cup of tea contains 175 g of water at a temperature of 85.0 °C. Milk at a temperature of 4.5 °C is added to the tea and the temperature of the mixture becomes 74.0 °C.

(i) Show that the internal energy of the water decreases by about 8 kJ as its temperature decreases.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(2)

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(ii) Calculate the mass of milk that was added to the tea. State an assumption that must be made.

Specific heat capacity of milk = 3900 J kg^{-1} K^{-1}

(3)

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Mass of milk = ...

Assumption

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(Total for question = 7 marks)

Q4.

Water at 100 °C turns into steam at 100 °C.
Which of the following statements is true?

☒ **A** The internal energy is unchanged, but the kinetic energy of the molecules increases.

☒ **B** The internal energy is unchanged, but the potential energy of the molecules increases.

☒ **C** Both the internal energy and the kinetic energy of the molecules increase

☒ **D** Both the internal energy and the potential energy of the molecules increase

(Total for question = 1 mark)

Q1.

A fine-beam tube is used for investigating properties of electrons.

An electron beam is produced inside a spherical glass bulb. The bulb contains neon gas at a very low pressure.

The neon gas is at a pressure of 1.25 Pa and a temperature of 25 °C.

Calculate the number N of neon atoms inside the bulb.

bulb diameter = 16.0 cm

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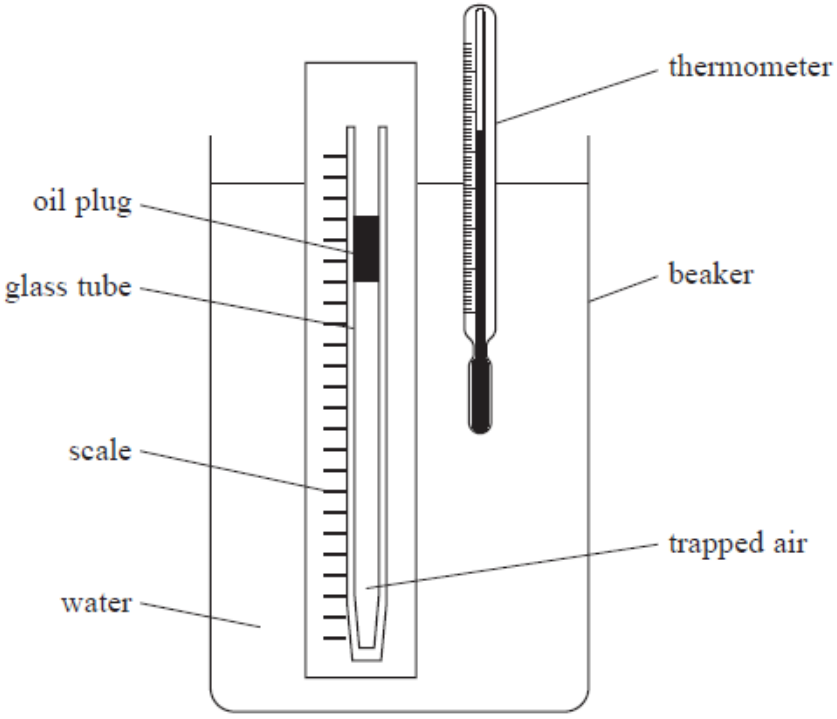
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N = ...

(Total for question = 4 marks)

Q2.

A student investigated how the volume of a fixed mass of air varies with the temperature of the air. She used the apparatus shown.



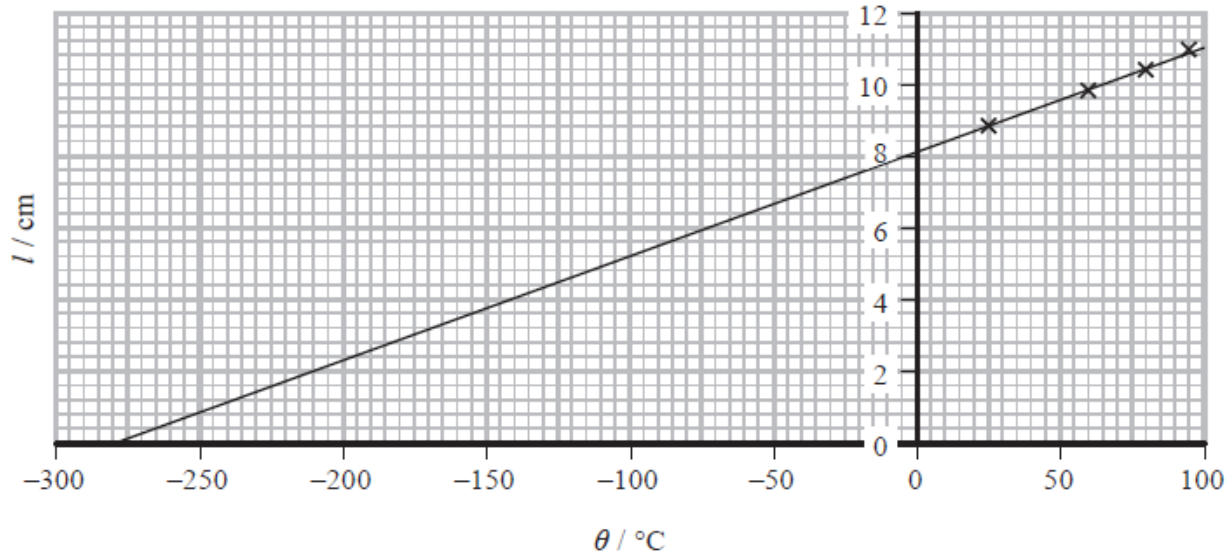
A glass tube was sealed at one end. A plug of oil trapped a length *l* of air in the tube. The water in the beaker was heated to a temperature *θ*. The corresponding value of *l* was measured. This was repeated for a range of temperatures.

The thermometer had a resolution of 0.5 °C. The scale had mm divisions.

The student's results are shown in the table.

θ / °C	*l* / cm
24	8.8
60	9.8
78.5	10.3
95.5	10.9

The student plotted a graph of *l* against *θ* as shown.



(i) Explain the significance of the intercept on the *x*-axis.

(3)

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(ii) The student wrote a report of the investigation in her lab book. In the conclusion she wrote:

"In this investigation uncertainties were minimised by selecting measuring instruments with a high resolution. The points lie on a perfect straight line, indicating that the investigation is accurate."

Discuss the student's conclusion.

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(Total for question = 7 marks)

Q3.

When a large potential difference is applied to a discharge tube, the gas in the discharge tube emits coloured light. When this light is passed through a diffraction grating, an emission spectrum which is made up of a series of lines of different wavelengths may be seen.

The photographs show the spectra produced from a tube containing hydrogen and a tube containing helium.

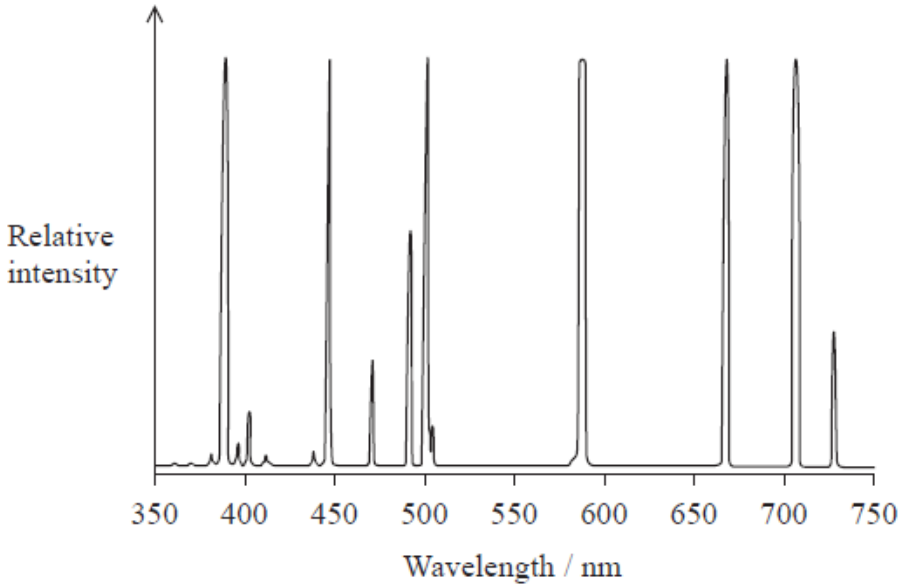
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The graph shows that the lines are not at a single wavelength. This effect is known as thermal Doppler broadening and occurs because of the random motion of the helium atoms.

(i) Explain why the thermal motion of the helium atoms causes the broadening of the spectral lines.

(2)

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(ii) The width of a line may be used to determine the speed of the atoms in the gas and hence the temperature of the gas.

The spectral line with wavelength 587 nm for a particular tube containing helium has a width of 6×10^{-3} nm.

(1) Show that this corresponds to a speed, for a helium atom, of about 1500 m s^{-1}.

(2)

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(2) Assuming that this is the root mean square speed for the helium (He 4) atoms in the tube, calculate the temperature of the gas in the tube.

(3)

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Temperature = ...

Q4.

The absolute temperature scale is a theoretical scale proposed by Lord Kelvin.

On this scale, zero is the temperature at which

☒ **A** all gases become liquids.

☒ **B** an ideal gas would exert no pressure.

☒ **C** the Celsius temperature is −373 °C.

☒ **D** water freezes.

(Total for Question = 1 mark)

Q5.

A student carries out an experiment to investigate how the volume occupied by a gas depends upon the temperature.

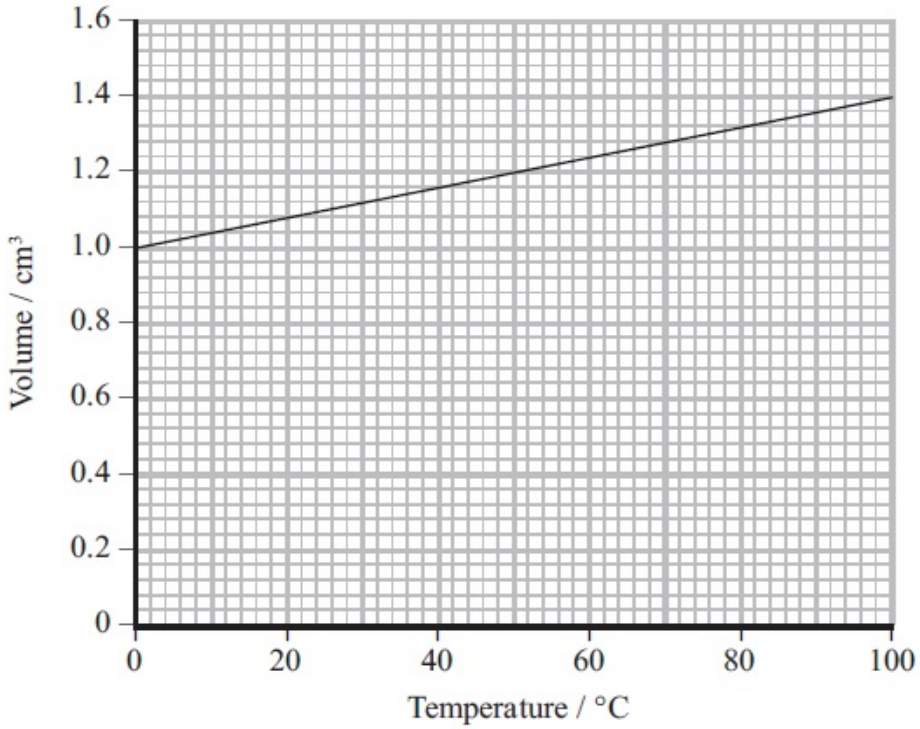
(a) What variables must the student control in this investigation?

(2)

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(b) The following graph is obtained.



Explain how graphs such as this provide evidence for an absolute zero of temperature.

(2)

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(Total for question = 4 marks)

Q6.

An old type of camping lamp used a 'gas mantle'. The gas mantle is heated by the gas flame on the lamp and emits a bright white light. Gas mantles used to contain thorium-230.

Thorium-230 decays by alpha emission to form an isotope of radium. A student keeps a radioactive gas mantle in a sealed polythene bag. The student suggests that over a period of a year a significant volume of helium gas will be collected, since an alpha particle is a helium nucleus.

A particular gas mantle contains 5.18×10^{-5} g of thorium-230.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^{4} Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms

half-life of thorium-230 = 75 400 years

number of seconds in 1 year = 3.15×10^{7}

(4)

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(ii) Determine the volume of helium gas that could be collected in a year as a result of alpha emission.

Assume that the temperature is 22.0 °C and the pressure is 1.00×10^{5} Pa.

(4)

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Volume = ...

(iii) Calculate the root mean square speed of the atoms in the helium gas at a temperature of 22.0 °C.

(3)

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Root mean square speed = ...

(Total for question = 11 marks)

Q7.

The average kinetic energy of the molecules in an ideal gas is

☒ **A** directly proportional to the square root of the absolute temperature.

☒ **B** directly proportional to the absolute temperature.

☒ **C** independent of the absolute temperature.

☒ **D** inversely proportional to the absolute temperature.

(Total for question = 1 mark)